How a three-step approach to knowledge-based machinery management can help keep your machinery online

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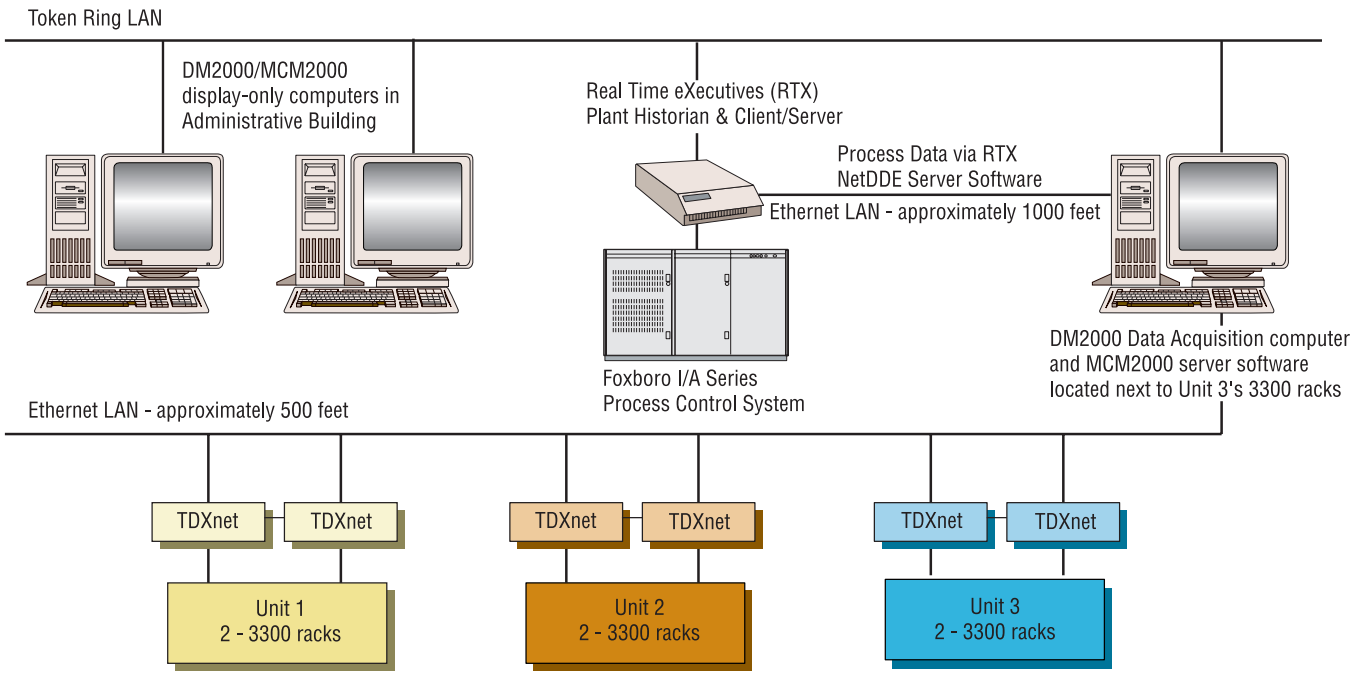
The Navajo Generating Station (NGS) is Arizona's largest coal-fired electric generating station, producing enough electricity for 500,000 customers in Arizona, California, and Nevada. It is located on the Navajo Indian Reservation in northern Arizona, 4½ miles east of Page, Arizona. The total output of the station's three main units is approximately 2,250,000 kW. In late 1994, the engineering staff at NGS began to develop a comprehensive plan for the protection and management of the three main units. The plant's goal was to increase the interval between major outages to seven years. To accomplish this difficult objective, NGS Engineering knew that more information about the machines would need to be gathered. This information would include process-related parameters and vibration information in a combined database for efficient data reduction and analysis. This project would involve specifying the right technology and using partners with the necessary experience to put this vision together.

Navajo Generating Station.



Navajo Generating Station DM2000/MCM2000 architecture.

Step one – Machinery protection transducers and monitors

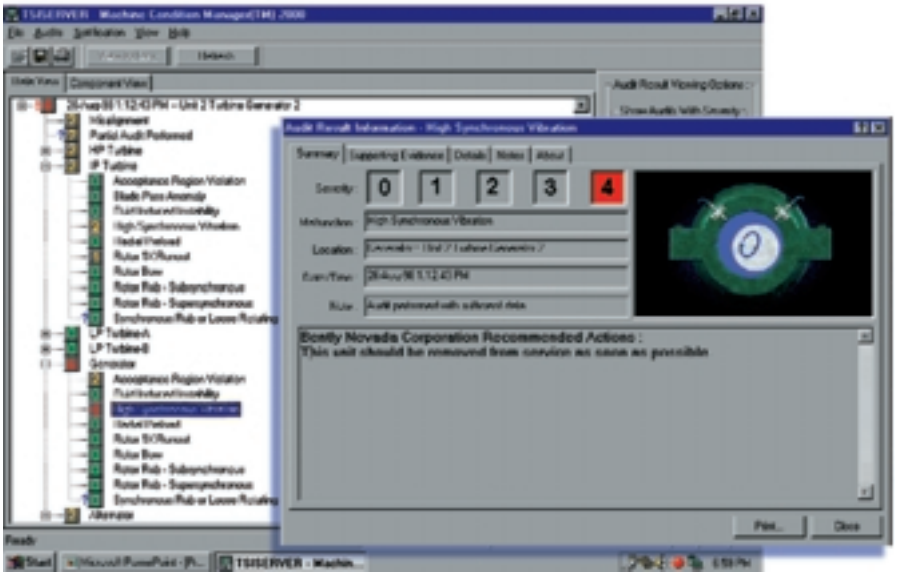
While the existing system, based on shaft-rider transducers, had served NGS for many years, the new outage schedule demanded much more dynamic and process-related information than their current system could supply. The first step in the process would be to specify the transducers necessary to properly monitor machine condition. NGS chose Bently Nevada transducers and monitors for a new Turbine Supervisory Instrumentation (TSI) system to be installed on all three units. XY proximity transducers would be installed at each radial bearing, and transducers would be installed for eccentricity, case expansion, differential expansion, thrust, and rotor speed. The 3300 Machinery Protection System was installed to provide online indication for all the new TSI parameters. Unit 3's TSI system was installed in October 1996, Unit 2's TSI was installed in January 1997, and Unit 1's TSI was installed in January 1999.

"We were very impressed with Bently Nevada's commitment to this project. The team from Bently did an excellent job supporting us with our new TSI system."

Tom Abdali,
Sr. Engineer
Navajo Generating Station

Step two – Machinery Management Architecture

With the goal of a major outage only every seven years, NGS's Engineering department also had to find ways to proactively determine machinery condition by correlating vibration information with process-related conditions. Having access to all this information would enhance the plant's ability to manage a machine's condition before an alarm level was exceeded. NGS had recently installed a new control system in the plant. This Foxboro control system was installed as part of the plant's ongoing effort to aggressively maintain its standards of air quality by installing new scrubber systems on each of the main units. The machinery management architecture for NGS would integrate the process information from the Foxboro DCS with the vibration information from Bently Nevada's 3300 Machinery Protection System in a database in the Data Manager® 2000 (DM2000) Machinery Management System.



A typical Machine Condition Manager™ 2000 system screen which displays recommended actions.

The plant chose Bently Nevada's DM2000 System, along with a process historian and client/server software program from Real Time eXecutives, Inc. (RTX), to take advantage of their chosen platform for moving information within NGS, Windows NT. The RTX software program collects, stores, and provides both "live" and historical process data for integration with and into other applications, such as DM2000, within NGS. The RTX System serves "live" process information to the DM2000 Data Acquisition Computer System via NET DDE. The DM2000 System connects directly to the 3300 Systems for each unit via an Ethernet communications link to Bently Nevada's TDXnet™ Communications Processor. These Communications Processors provide online dynamic and static information to DM2000 under steady state (constant speed) and transient (startup and coastdown) conditions. The DM2000 Data Acquisition computer is then linked over the plant's Token Ring Local Area Network (LAN) to the NGS Engineering department's desktop computers which run Data Manager® 2000 and Machine Condition Manager™ 2000 (MCM2000) software. Using a project team made up of Bently Nevada service personnel, integration of the RTX and DM2000 Systems took place in August 1998.

"The MCM2000 alerted us to potential problems we had, which would have gone unnoticed with the instrumentation we were using previously. Some bearings were determined to be excessively loaded, and we will use this information to make adjustments to our alignment procedures in the future. It also alerted us to some minor steam whirl conditions with different steam flow conditions. We are also working with Bently personnel to create custom rules that will allow us to have the MCM 2000 system bring to our attention situations that are unique to our turbine/generator train, based on our experience."

Ed Weeks,
Principal Engineer
Navajo Generating Station

Step three – Automate data reduction and diagnosis

The final piece of the machinery management puzzle at NGS was finding a way to automate the data reduction and diagnosis from the massive database that was now being gathered. Bently Nevada's MCM2000 System was chosen to provide Decision Support℠ to NGS engineering. MCM2000 operates on the combined RTX and DM2000 database to automatically audit machine condition, based on the dynamic and static information being gathered. MCM2000 is not a menu-driven "expert" system, but rather an automated Decision Support℠ system that is intended to make the NGS engineering staff more efficient. MCM2000 can get "smarter" about each machine through optimization by NGS personnel. (Installation and initial optimization of MCM2000 was performed by Bently Nevada project personnel in August 1998.)

Hardware alarm triggers immediate results

Within weeks of initial commissioning of the DM2000 and MCM2000 systems, a high vibration event occurred which exceeded hardware alarm setpoints in the 3300 Machinery Protection System. A machinery audit by MCM2000 was automatically initiated. MCM2000's initial malfunction diagnosis pointed to unbalance of the generator rotor caused by thermal sensitivity of the generator to MW and MVAR loading. One possible source of such a condition is the deterioration of the generator rotor field windings. Electrical shorting between the windings was causing localized cooling, thermally bowing the rotor. With this in mind, NGS implemented a short-term fix by successfully balancing the generator rotor to compensate for its thermal sensitivity. This kept the unit online during a summer of exceptionally high power demand.

Custom rule application

By using the 1X and 2X Acceptance Regions in DM2000, NGS was able to detect relatively minor shifts in LP turbine vibration that were well below the 3300 Alert setpoints. The shifts were large enough to exceed the Acceptance Region boundaries, however, resulting in a "software alarm" within DM2000. The vibration shifts were related to improper operation of the LP steam seals. NGS plans to incorporate a custom rule with MCM2000 which specifically correlates steam-seal valve settings with LP vibration, so this problem can easily be detected in the future.

A journey, not a destination

The state-of-the-art machinery protection and management systems being used at NGS were a result of a well-planned vision and execution by an experienced project team from NGS, Bently Nevada, and RTX. NGS's Engineering department had a vision of what they wanted to achieve and then used the appropriate technology and personnel to achieve that vision. Using their new hardware and software has enabled the plant to become more efficient. Now, NGS can concentrate on teaching employees how to effectively use the hardware and software.